Adding STAR/ALICE UE subtraction routine to sPHENIX

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Underlying Event (UE) Subtraction

- As we all know, in HI collisions the soft UE event affects all jet observables
  - Combinatorial jets
    - Important issue to discuss→ beyond the scope of this talk
  - Background underneath "true" signal jets
    - Smears jet p_T → JER
    - Adds energy/momentum to the jet → JES
- Subtraction techniques correct the JES for the UE, necessary for unfolding and intreptation
  - Non-diagonal Response Matrices do not yield consistent and stable results

Underlying Event (UE) Subtraction

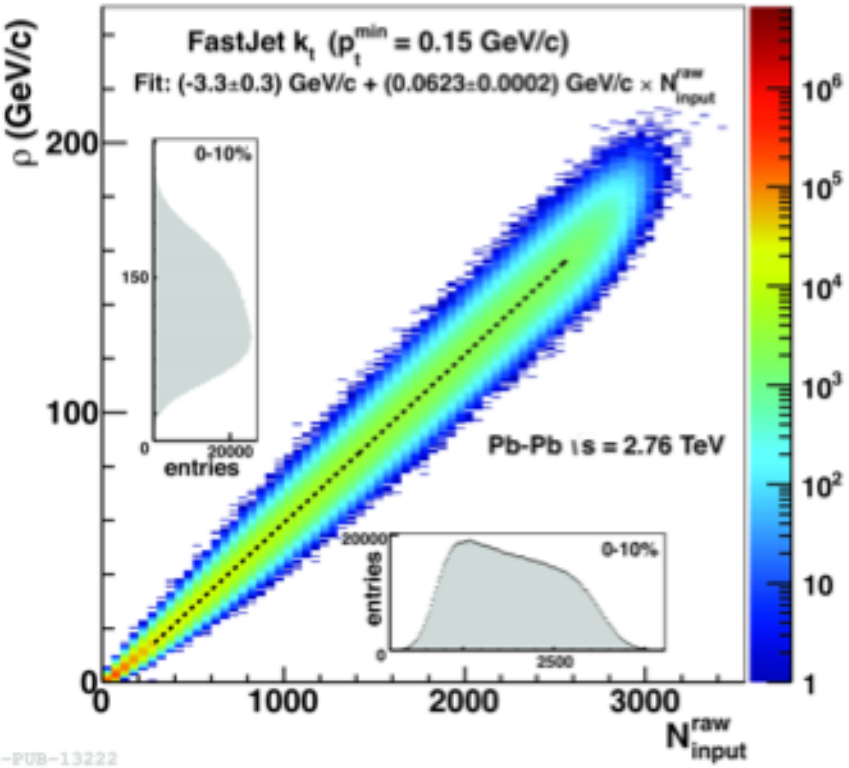
- During the separation of PHENIX and sPHENIX software the UE subtraction was not included
  - MIE studies were based on this UE subtraction
- This is required to make real Au+Au jet performance plots
- Ideally multiple UE subtraction methods would be available, as some observables may perform better with one versus another
- Here I propose incorporating the “STAR/ ALICE” Method

ALICE/STAR background subtraction Method Jet Median Approach

- ρ : **median** of $p_{T,kTjet} / A_{kTjet}$
  - 2 leading jets removed
  - Determined event-by-event
- ρ not corrected for detector effects
  - Model independent
  - Data driven
- Subtracted on a jet-by-jet basis $p_{T,jet}^{unc} = p_{T,\mathrm{jet}}^{rec} - \rho A$

* May be sensitive to jet fragments outside k_T jet cone

JHEP 1203:053, 2012
(arxiv:1201.2423)



ALICE/STAR background subtraction Method Jet Median Approach

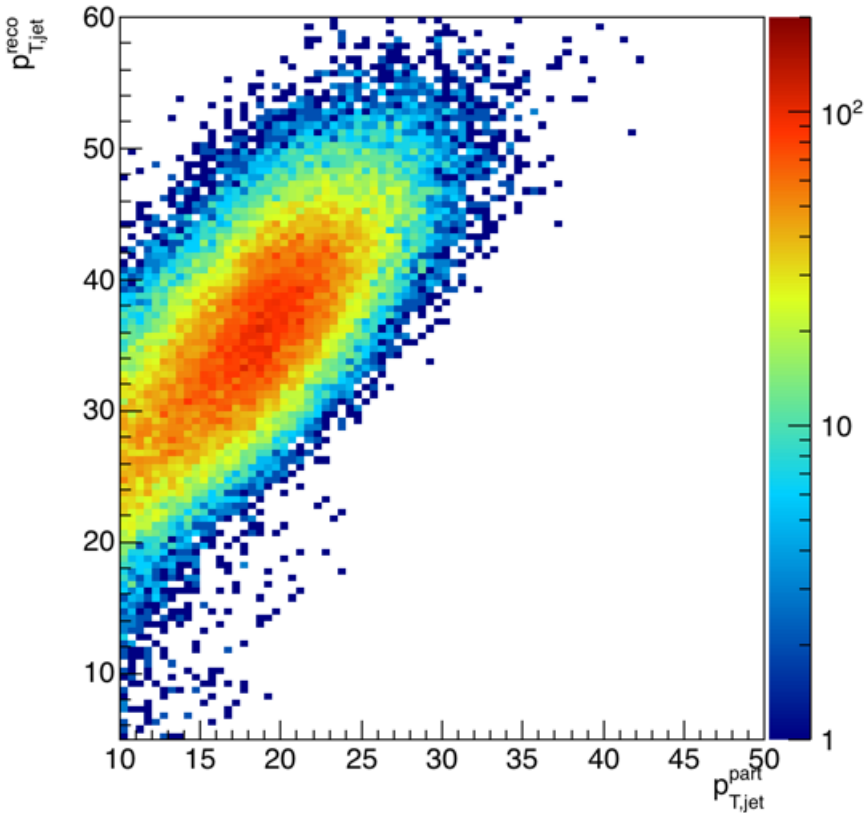
- The background depends on
  - Centrality
  - Event Plane
  - Constituent cut
- One can modify ρ using the EP angle and v_2
- One question is what is the best R value to use
  - In HI collisions a small R is used, more susceptible to jet fragments outside the k_T cone for ρ
    - 2 Leading jets not enough?
  - Larger R for background → Acceptance/boundary issues

ALICE/STAR background subtraction Method Jet Median Approach

- Already incorporated into fastjet!!
  - This makes implementation technically straight forward
- Does not require any "constituents" to be altered
  - Can be thought of as almost an after burner
- Will require some changes to core sPhenix jet classes
  - More later
  - Ideally set as an "option" that someone can use
  - Only works on uncorrected jet structures (AFAIK)

ALICE/STAR background subtraction Method
Jet Median Approach – Toy Model

- PYTHIA run with
  - $15 < p_{T,hat} < 25$ GeV
  - "Background" thrown with a Boltzmann distribution
    - $\langle p_T \rangle = 0.5$ GeV
    - 1000 background particles
- Jet finder parameters
  - R = 0.4
  - $p_{T,min} = 0.150$



JES offset without subtraction

$$p_{T,jet}^{Reco} > 5$$

$$p_{T,jet}^{Part} > 10$$

$$|dR| < 0.2$$

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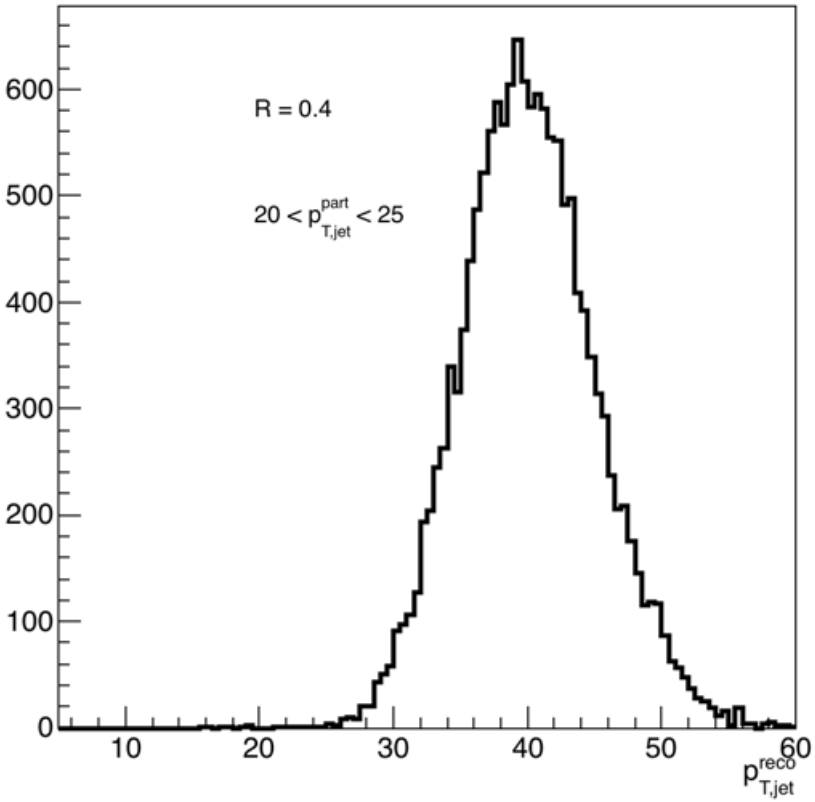

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ALICE/STAR background subtraction Method Jet Median Approach – FJ Implementation

- JetMedianBackgroundEstimator bge(rho_range, jet_bkgd_def, area_def);
  - rho_range → Selector, acceptance in eta/phi
  - jet_bkgd_def → Algorithm to be used (k_T, R ~ 0.4)
  - area_def → Active area
- Note: Any fastjet acceptance selector can be used with this algorithm
  - Detector acceptance (R away from boundary?)
  - Removal of hardest jets?
  - η/ϕ strips?

ALICE/STAR background subtraction Method
Jet Median Approach – FJ Implementation

- JetMedianBackgroundEstimator bge(rho_range, jet_bkgd_def, area_def);
- Subtractor subtractor(&bge);
  - Defines the subtractor with this background defintion
  - Multiple subtractors are allowed in an analysis
- bge.set_particles(backparticles);
  - Backparticles → Vector of PseudoJet
  - NOTE: Do *not* use pre-clustered particles here
  - Can use selectors on the vector beforehand
    - $P_{T,min}$ is common → Same criteria needed for signal and background

ALICE/STAR background subtraction Method Jet Median Approach – FJ Implementation

- JetMedianBackgroundEstimator bge(rho_range, jet_bkgd_def, area_def);
- Subtractor subtractor(&bge);
- bge.set_particles(backparticles);
- Next one runs over the collection of signal jets (clustered in the usually way)
  - PseudoJet jet = jets_signal[i];
  - PseudoJet subtracted_jet = subtractor(jet);
  - Note: This is $p_{T,sub} = p_{T,reco} - \rho A$, if $p_{T,sub} < 0$ then FJ sets $p_{T,sub}$ to 0

ALICE/STAR background subtraction Method
Jet Median Approach – Case Study

- PYTHIA run with
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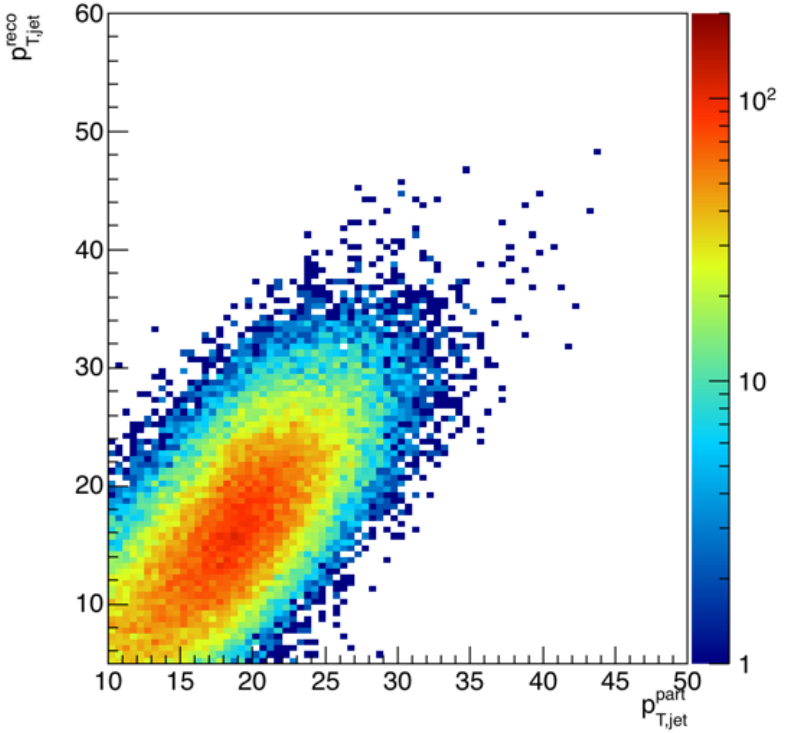

JES → Much closer with subtraction!

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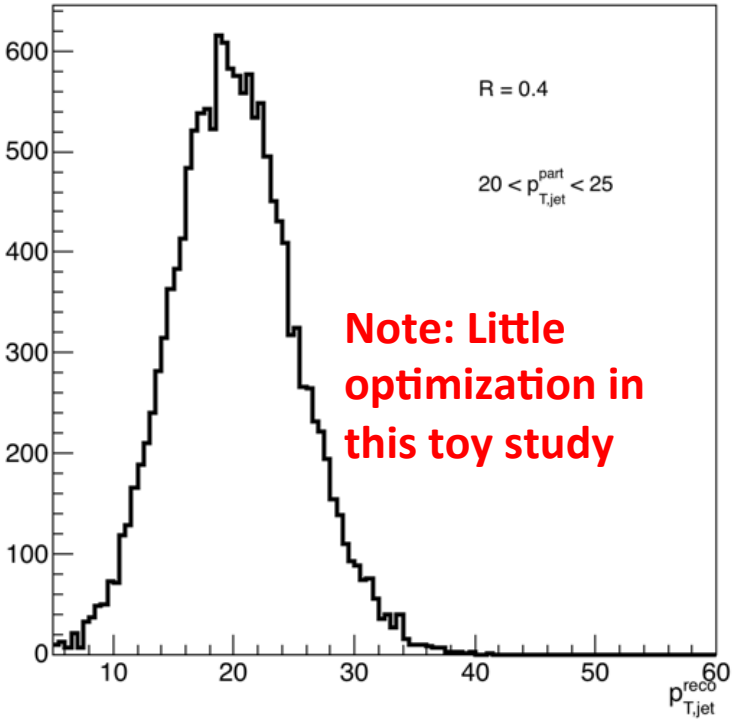

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ALICE/STAR background subtraction Method Implementation in sPHENIX

- Strategy → This should be implemented in an unobtrusive fashion
- Event-wise quantity ρ (bge.rho())
  - At least to start ….
  - "Who" should own this?
- Using Fun4All_G4_sPHENIX.C, the jet evaluator returns 2 Ntuples
  - reco jet => max truth jet
  - truth jet => best reco jet
  - Initial implementation → "owned" by the jet

ALICE/STAR background subtraction Method Implementation in sPHENIX

- Event-wise quantity ρ → Who should own this?
- Jet evaluator returns 2 Ntuples w/jet parameters
  - Propose to save both A and ρ
    - Later implementations may want to include v_2 modulation
    - Subtraction performed "by hand"
    - Allows negative p_T jets in analysis (generally combinatorial jets)
    - Allows bg to be calculated later (or not) and added to the jet collection without modifying any initial parameters
  - Another option is to overwrite the jet kinematics
    - I really don't like this one
  - Or save $p_{T,sub}$ alone

ALICE/STAR background subtraction Method Implementation in sPHENIX

- Event-wise quantity ρ → Who should own this?
  - Jets own ρ
- This would require changes to:
  - coresoftware/simulation/g4simulation/g4jets/JetV1.h
    - Getter and setter for Area and ρ
      - Default negative → No accidental usage
    - Add Area and ρ as member variables
    - Getter for "subtracted" p_T
  - coresoftware/simulation/g4simulation/g4jets/JetV1.C
    - Getter for "subtracted" p_T
  - Why do we have JetV1 and Jet? Was a merge supposed to happen at some point?

ALICE/STAR background subtraction Method Implementation in sPHENIX

- Would require new files:
  - "UEreco.h, UE.recoC" + "UE.h, UE.C"
    - UE.h and UE.C would be quite simple
  - coresoftware/simulation/g4simulation/g4jets/
  - Think about naming convention → Multiple UE routines
- Implementation would be similar to JetReco
  - Use fast jet on input objects (towers, whatever)
  - Add ρ to an input jet stream (select again hard jets)
  - Place PHObject UE on "top node" → to the DST
- Note: This should be done so as to allow 4-vector UE determination, etc in the future

ALICE/STAR background subtraction Method Implementation in sPHENIX

- This would require no changes to coresoftware/ simulation/g4simulation/g4jets/JetReco.*
  - Background method will attach ρ to jets directly
  - In fact, most header files should remain the same as the change will live mostly in the Jet and in the separate UE algorithm
- This would require a small change to:
  - macros/macros/g4simulations/ Fun4All_G4_sPHENIX.C
    - Bool switch for background (default off)
    - In jet reco loop -> Call UEreco (if bool is on)

ALICE/STAR background subtraction Method Implementation in sPHENIX

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ALICE/STAR background subtraction Method Implementation in sPHENIX

- Lastly (I believe) this will require changes to:
  - coresoftware/simulation/g4simulation/g4eval/JetEvaluator.C
- Mainly we need to add a gptue or something of this nature to the Ntuple
  - And in the body, include it using the getter that will be part of the Jet class
- These changes will allow a new person to run with this UE subtraction, and should make it possible for anyone to incorporate it into her code

ALICE/STAR background subtraction Method Lightweight Background Methods

- Testing background subtraction methods/HI observables require a reasonable background
  - It's not always practical to run HIJING + PYTHIA
  - Not necessary for initial checks of an observable
  - Or to test UE subtraction funcationality
- Add ability to run fluctuating background
  - For instance, add a random generated gaussian to tower ADC prior to conversion
  - Harder to do with tracking, perhaps should wait on this

Conclusions/timeline

- I am at BNL all week → A time for productivity!
- Add UE methods by Wednesday (new code, won't effect anyone)
- Locally (to my machine) change core codes by Friday
  - Verify over the weekend that these changes do not effect anything else
    - Perhaps a volunteer would help!
- Push on Monday … Maybe we use a "V2" or something like this for that week so others can confirm

Conclusions/timeline

- Push on Monday
- Need to evaluate with a realistic background and unfolding
  - UE functionality with this method will be “there” but it will also need to be optimized, etc.
    - Next week I will spend time insuring that optimization “tweaks” are options that can be manipulated so we can freeze the code
- Once the UE is in, I will work on a lightweight background method, unless someone else would like to grab that!